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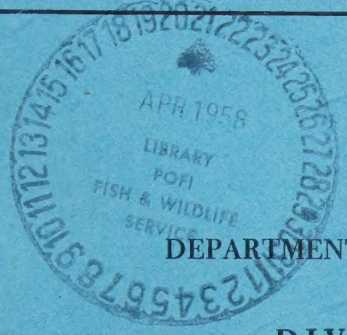

Union of South Africa

DEPARTMENT OF COMMERCE AND INDUSTRIES

DIVISION OF FISHERIES

INVESTIGATIONAL REPORT No. 30

THE SOUTH AFRICAN PILCHARD

(Sardinops ocellata)

PRELIMINARY REPORT ON FEEDING OFF THE WEST COAST, 1953-56

BY

D. H. DAVIES, M.Sc., Ph.D:

(Senior Professional Officer, Division of Fisheries, now *Institute of Marine Resources*, University of California.)

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1. Summary.

The purpose of this investigational report was to examine and review the data related to the feeding of the South African pilchard which has been collected in the course of the Pilchard Research Programme. Although the examination of stomach contents was carried out from 1950 onwards, the data obtained prior to June, 1953, are not considered to be of sufficient value for inclusion. This investigation is therefore based on data collected during the period June, 1953, to December, 1956. The data were derived from the examination of the stomach contents of 16,664 fish caught in the commercial fishing area off the west coast of the Union of South Africa (see Fig .1).

As a result of this investigation the following findings were made:—

(1) The South African pilchard is primarily a filter feeder but may also be a particulate feeder.

(2) The food of the pilchard off the west coast of the Union of South Africa is plankton; the organisms eaten belong to many different groups and vary in size from minute diatoms to relatively large salps.

(3) The food of the pilchard may be broadly differentiated into phytoplankton and zooplankton, the former being eaten to a far greater extent than the latter during the greater part of the year.

(4) The mean ratio of phytoplankton to zooplankton in pilchard stomachs for the year was found to be 2: 1.

(5) The relationship between the occurrence of phytoplankton and zooplankton in pilchard stomachs throughout the year is inverse. Large quantities of phytoplankton are consumed by pilchards in autumn and spring when comparatively small amounts of zooplankton are eaten; in summer and winter less phytoplankton is eaten and larger amounts of zooplankton are consumed.

(6) The phytoplankton eaten by the pilchard consists mainly of diatoms; diatoms were recorded in pilchard stomachs in considerable quantities during every month except December when no pilchard samples were obtained. They were eaten in greatest quantity in spring, in considerable quantities in autumn and in smaller amounts in summer and winter.

(7) Pilchards feeding in the St. Helena Bay area show an apparent preference for phytoplankton in their feeding and regularly consume large quantities dependent on its availability in the area. This apparent preference for phytoplankton may be one of the main reasons for the congregation of pilchard shoals in the St. Helena Bay area.

(8) The pilchard feeds on zooplankton at times when the abundance of phytoplankton has become diminished.

(9) The most important group in the zooplankton eaten by pilchards is the *Copepoda*; copepods are eaten throughout the year but occurred in stomach contents in largest numbers in summer and winter.

(10) Pilchards may feed more actively in summer than at other times of the year.

2. Introduction.

Since the migrations of pelagic species of fish must to some extent be related to the availability of their food supply, it is important to know the composition of that food supply, particularly for a species of high commercial value such as the pilchard.

When the Pilchard Research Programme was begun in 1950, samples of pilchards, each consisting of 50 fish, were taken from the commercial catches and examined at the shore stations. A full account of this sampling procedure, routine, etc., is given by Davies (1956*a*). A general assessment of the feeding of the pilchard was made for each sample by means of a rough examination of the contents of the stomach and alimentary tract of each fish.

All samples of pilchards used in this feeding study were taken from commercial catches made off the west coast of the Union of South Africa between Dassen Island and a point 10 miles to the north of Lambert's Bay (see Fig. 1). The majority of the catches were made in the area between Cape

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Columbine and Lambert's Bay and this area is generally referred to in the report as the St. Helena Bay area.

The accurate assessment of the feeding of any animal is seldom a simple matter and even when it is attempted with every possible facility, it may still produce results which are not an entirely accurate reflection of what happens in nature.

At the start of the Pilchard Research Programme, research resources were comparatively limited, particularly in relation to personnel. For this reason, certain aspects of the work relating to the biology of the pilchard were carried out with modified or reduced facilities only. Feeding studies fell into this category and up to the middle of 1953 consisted of little more than a rough visual estimate of whether the fish had been eating phytoplankton or zooplankton based on the overall colour of the contents of the alimentary canal, e.g. " green feed " indicated that phytoplankton had been consumed and " red feed " indicated that zooplankton had been consumed.

In 1953, however, one of the two shore stations, viz. Lambert's Bay, was closed down and the personnel doubled at the remaining shore station at Stompneusbaai. This permitted a more detailed approach to the problem of the feeding of the pilchard.

After careful examination of the data obtained from feeding studies carried out from 1950 to 1953, it was decided that no information contained in these data could not also be found in the data obtained in the later period 1953 to 1956, and it was therefore decided to make use of the latter data only.

3. Method.

Various methods are used in the evaluation of the organisms eaten by fish. The method used depends on many factors including the type of fish, its way of feeding, the organisms on which it feeds, the possibilities of obtaining adequate samples, etc. Whichever method or combination of methods is chosen the final object is to obtain an accurate qualitative and quantitative assessment of the food of the fish.

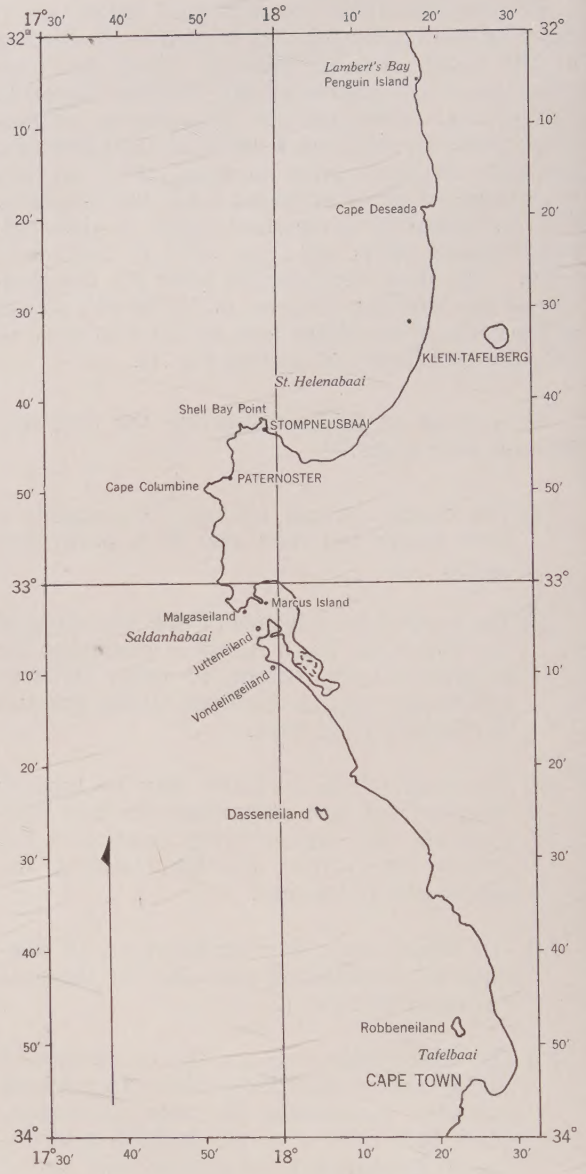

FIG.1 THE WEST COAST

Trigsurvey, 1956. Government Printer, 1956.

Owing to the fact that a comparatively small number of personnel was available for the execution of all aspects of research into the biology of the pilchard, the feeding studies undertaken had to be limited accordingly.

The procedure adopted was as follows:—

(1) The entire stomach (see Item 2 below) of each fish in a sample of 50 pilchards was cut open, a rough estimate of its fullness made and the contents examined macroscopically and listed on the sample sheet. The degree of fullness was expressed in terms such as full, $\frac{3}{4}$ full, $\frac{1}{2}$ full, nearly empty and empty. These were later converted into index numbers, viz. full = 10, $\frac{1}{2}$ full = 5 and so on.

(2) The entire stomach, including the cardiac stomach, the pyloric stomach and the fundus (see Plate 1), was removed from each of the first six fish in the sample by cutting the posterior end of the oesophagus and by cutting away the intestine. The six stomachs had previously been cut open for rough examination (see Item 1 above) and the contents were then transferred into a petri dish with the aid of a wash bottle. They were then examined microscopically.

(3) A rough count of the various organisms present in a sample of the lumped stomach contents of the six fish was made, their relative size taken into consideration and then expressed as a percentage of the total stomach contents. Where a count was not possible, for example when digestion was well advanced, a rough estimate of the relative proportions of the predominant organisms present was made.

As it was invariably found that the pilchards comprising a sample possessed stomachs with almost identical contents and in a similar state of repletion, it was possible to express the stomach contents of the entire sample as an approximate mean percentage composition based on rough counts but taking into consideration the relative size of the organisms concerned. For example, 50 euphausiids occupied a far greater volume than 50 copepods and the estimated percentage composition was adjusted accordingly. No allowance was, however, made for the relative food value of the various organisms eaten.

It is evident that with a method so lacking in refinement, little other than a general impression of the feeding of the pilchard could be obtained.

4. Feeding of the Pilchard.

(a) Organisms recorded in stomach contents.

During the course of the examination of the stomach contents of pilchards obtained from the commercial catches in the St. Helena Bay area off the west coast of the Union of South Africa during the period June, 1953, to December, 1956, the following organisms were recorded:—

DIATOMS.

Thalassiosira spp.
Coscinodiscus spp.
Rhizosolenia spp.
Chaetoceros spp.
Nitzschia spp.
Biddulphia spp.
Stephanopyxis spp.
Pleurosigma sp.
Guinardia sp.
Corethron sp.
Pseudoeuonotia sp.
Thalassionema sp.
Lithodesmium sp.
Planktoniella sol
Asterionella japonica

DINOFLAGELLATES.

Ceratium spp.
Peridinium spp.
Dinophysis spp.
Orthoperidinium spp.
Goniaulax sp.
Prorocentrum sp.
Biceratium sp.
Noctiluca sp.

PROTOZOA.

Tintinnus sp.
Rhabdonella sp.
Radiolaria spp.

BRYOZOA.

Cyphonautes larva.

COPEPODA.

Calanus spp.
Eucalanus spp.
Paracalanus parvus
Rhincalanus nasutus
Centropages brachiatus
Oithona similis
Metridia lucens
Oncaea spp.
Copilia spp.
Nauplii
Eggs

EUPHAUSIACEA.

Euphausia lucens
Nyctiphanes capensis
Calyptopis stages
Furcilia stages
Eggs

CLADOCERA.

Evadne sp.
Podon sp.

AMPHIPODA.

Themisto sp.

OSTRACODA.

Conchoecia sp.

CIRRIPEDIA.

Nauplii
Cyprid larvae

STOMATOPODA.

Larval stages of *Squilla armata*

DECAPODA.

Zoea larvae of crabs
Zoea larvae of *Sergestes armatus*

TUNICATA.

Oikopleura sp.
Thalia democratica
Doliolum sp.

MOLLUSCA.

Limacina sp.
Veliger larvae of *Gastropoda*
Larvae of *Lamellibranchiata*

CHAETOGNATHA.

Sagitta friderici

PISCES.

Mainly ova of *Sardinops ocellata*
Various larvae

The above list includes all the organisms which have so far been obtained in the stomachs of pilchards. Although fairly comprehensive, there is no doubt that more detailed examination of stomach contents will reveal the presence of additional species. It will be noticed that in some groups, in particular the diatoms and dinoflagellates, further identification is necessary.

Attention is drawn to the fact that the list of food organisms above is related to pilchards within the size limits of the commercial catches (Davies, 1957), and does not necessarily include organisms eaten by pilchards outside these size limits. The food of juvenile pilchards, for example, is not included.

(b) Monthly variation of feeding.

The food organisms recorded in the stomachs of pilchards examined in the samples taken from the commercial catches in the period June, 1953, to December, 1956, were expressed as a percentage composition of the entire stomach contents and grouped under various headings such as *dinoflagellata*, *euphausiacea*, etc., as monthly means (see Tables 1–4). These data have been illustrated by means of histograms (see Plates 2–11).

The percentage composition of the main groups of food organisms in pilchard stomachs was averaged for each month of the period 1953–56 (see Table 5) and illustrated by means of graphs (see Plate 12 for main groups in the phytoplankton and Plate 13 for main groups in the zooplankton).

The monthly variations recorded in the general diet of the pilchard were as follows:—

Phytoplankton (including Diatoms, Dinoflagellates and Unrecognisable Phytoplankton).

Owing to the fact that a large proportion of the phytoplankton in pilchard stomach contents was partly digested and was therefore not recognisable except as phytoplankton and could not be differentiated into diatoms and dinoflagellates, the values obtained for these two groups do not individually reflect their true monthly or seasonal variation. For example, in a particular month the figure recorded for diatoms might have been very low while the figure for unrecognisable phytoplankton was very high. If a large part of the unrecognisable phytoplankton had in fact consisted of diatoms, the figure for diatoms would then have been quite false.

It was considered advisable therefore to combine the three groups, i.e. diatoms, dinoflagellates and unrecognisable phytoplankton, and treat them as one group, viz. phytoplankton, for purposes of comparison of monthly and seasonal variation.

Reference to Plate 12 (drawn from data contained in Table 5) and comparison of the graphs with those shown in Plate 16 (drawn from data contained in Table 6) shows that the general seasonal trend of

diatom variation in pilchard stomachs (see Plate 12) is rather widely different from that of the unrecognisable phytoplankton, particularly in the autumn months. The graphs of unrecognisable phytoplankton (see Plate 12) and phytoplankton in the stomachs (see Plate 16) are, on the other hand, almost identical.

The quantity of dinoflagellates recorded in stomachs was consistently low throughout the year, and it is doubtful whether the presence of this group makes any appreciable difference in the amount of phytoplankton recorded in the stomach contents of pilchards at any time of the year.

It seems likely therefore that the mean figures obtained for the quantities of diatoms in pilchard stomachs throughout the year are fictitious, and are more a reflection of the state of digestion of the phytoplankton in the stomachs than anything else.

The quantity of dinoflagellates eaten by pilchards is relatively small throughout the year (*see Plate* 12). *April is the month of maximum consumption of dinoflagellates, and coincides with the maximum occurrence of the dominant species of dinoflagellates in the plankton of the St. Helena Bay area according to counts made on a monthly basis* (de Jager, 1957).

As relatively small quantities of dinoflagellates are consumed by pilchards during the year, they are unlikely to affect the quantities of " unrecognisable phytoplankton " recorded each month. Consideration of a combination of the two groups *diatoms* and *unrecognisable phytoplankton*, should therefore provide a good indication of the seasonal variation of diatoms in the diet of the pilchard. In the remainder of this section, therefore, unrecognisable phytoplankton data have been included with diatom data and considered together as " diatoms ".

The monthly variation in the occurrence of diatoms in the stomach contents of pilchards during the period June, 1953, to December, 1956, followed a general trend similar to that shown in the graph (see Plate 12, graph No. 4).

Although the examination of pilchard stomachs showed that the smallest amounts of diatoms were eaten during January, they nevertheless comprised 33 *per cent of all organisms eaten by pilchards during this month. In February and March a sharp increase in the occurrence of diatoms in stomachs took place. During April, May, June and July, however, a continuous decrease in consumption occurred. From July through to September a sharp increase in the quantity of diatoms eaten took place and reached the maximum figure in October. A decrease occurred in November.* No results were obtained during December due to the absence of pilchards from the commercial fishing area.

During the period June, 1953, to December, 1956, certain *deviations* from the general trend of occurrence of diatoms in pilchard stomachs were observed.

In February, 1956, far fewer (less than half) diatoms occurred than in the same month in other years.

In July, 1954, hardly any (2 per cent) diatoms were recorded in stomach contents while the percentage composition for the same month in other years ranged from 24 to 70 per cent.

In November, 1954, large quantities (94 per cent) of diatoms were obtained while in the same month of 1955 only 15 per cent was obtained.

Calculated on a *seasonal basis*, the percentage composition of diatoms in the stomach contents of pilchards was as follows:—

Summer.....53 per cent.
Autumn.....67 per cent.
Winter.....55 per cent.
Spring.....84 per cent.

In general, diatoms occurred in pilchard stomachs in considerable quantities during every month with the exception of December when no records were obtained due to the absence of pilchards from the commercial fishing area. They were present in greatest quantity in spring, in considerable quantities in autumn and in smaller amounts in summer and winter.

Zooplankton.

(N.B. Certain items recorded in small quantities appear in Tables 1–5 but have been omitted in the histograms, Plates 2–11).

Protozoa.

Protozoa were recorded in the stomach contents of pilchards during the months April to September, i.e. mainly in the autumn and winter. They consisted of the following: *Tintinnus* sp., *Rhabdonella* sp. and a number of species of *Radiolaria*.

Protozoa were usually present in small numbers only (see Table 5). The largest numbers obtained (3 per cent) were recorded in April, 1956, and consisted entirely of *Tintinnus* sp.

It is considered that the *Protozoa* are of little importance in the feeding of the pilchard.

Copepoda.

Adult stages of more than fourteen species of copepod (see Section 4) *were recorded in the stomach contents of pilchards during every month except December* (when no pilchard samples were obtained in the St. Helena Bay area). Copepod eggs and *nauplii* were recorded from January to August and in October, but comprised only a small item among the food organisms eaten by the pilchard.

The genera most frequently recorded in pilchard stomachs were *Calanus*, *Centropages* and *Oithona*. Copepods were nearly always (except for December) present in pilchard stomachs and were at times recorded in large numbers.

It is doubtful, however, whether the results obtained reflect the full importance of this group, due to the fact that digestive action in the pilchard stomach causes the rapid disintegration of *copepoda* thus making identification difficult. Where a considerable period had elapsed between the time when the pilchard had eaten and the time when its stomach contents were examined, organisms such as diatoms with a more resistant structure remained in a recognisable state for longer than the less resistant copepods. Consequently in the recording of such stomach contents as these, the *copepoda* would not receive sufficient recognition or prominence.

It is likely that a large proportion of the " unrecognisable zooplankton " (see Table 5) consisted of *copepoda* (see Plate 13), and a more detailed study of the feeding of the pilchard would doubtless reveal a greater importance of *copepoda* in the diet of this fish.

According to the present data, *copepods occurred in greatest quantity in pilchard stomachs in summer and winter* (see Plate 13).

During the period June, 1953, to December, 1956, the main deviations from the general trend of occurrence of copepods in pilchard stomachs were that no copepods were recorded in September, 1954, and October, 1955.

Euphausiacea.

Adult euphausiids of two species (see Section 4) were recorded in the stomach contents of pilchards during the months of January to May and in July, August and October. Eggs, *calyptopis* and *furcilia* stages were recorded in small numbers during every month except January and December (no pilchard samples were obtained in December).

In October, 1955, considerable quantities (10 per cent) and in November, 1955, very large quantities (60 per cent) of euphausiid eggs were recorded in pilchard stomachs (see Table 3). This is in agreement with the records of euphausiid eggs in the plankton of the St. Helena Bay area where the largest numbers are present during the spring and summer months (Nepgen, 1957).

It is possible that euphausiids constitute a food supply of some importance at certain times of the year, for example July, 1954 (see Plate 4), when their occurrence in stomachs was as high as 10 per cent. The possible importance of highly nutritious organisms of large size such as euphausiids becomes even greater when it is borne in mind that the pilchard can become a particulate feeder whenever necessary (Davies 1956 *b*).

Cladocera.

Two species occurred in the stomach contents of pilchards on rare occasions only.

Amphipoda.

One species of *Themisto* was recorded in small numbers during January, March to May and July to September.

Ostracoda.

One species of *Conchoecia* was recorded in small numbers during every month except for December when no pilchard samples were obtained.

Cirripedia.

Larval stages of barnacles were recorded in small numbers during the months of May, August and September.

Stomatopoda.

Larval stages of *Squilla armata* were recorded in small numbers in February, August and September.

Decapoda.

Zoea larvae of crabs were recorded in small numbers in the months of February, July, August, September and October. *Zoea* larvae of *Sergestes* were recorded in August.

Tunicata.

Specimens of *Oikopleura*, salps and doliolids occurred in stomach contents on rare occasions.

Mollusca.

Limacina sp. and gastropod larvae were recorded in small numbers during all months of the year except February, September and December. Lamellibranch larvae were recorded in small numbers mainly in the spring months and on one occasion in large numbers in November (1955).

Chaetognatha.

Chaetognaths of one species were recorded in small numbers during the months of April, May and July to October. In August, 1953, larger numbers (4 per cent) were recorded.

Fish eggs.

Fish eggs were recorded in small numbers during the months of January, and from May to October. In September, 1955, larger numbers of eggs (3 per cent) were recorded.

The majority of eggs recorded in stomachs were pilchard eggs, including those recorded in September, 1955.

Fish larvae were recorded on rare occasions and were seldom in an identifiable state.

Unrecognisable zooplankton.

Unrecognisable zooplankton was a prominent item recorded during most months of the year. It is likely that it consisted to a large extent of the partly digested remains of copepods, and it is hoped that future, more detailed investigations into the feeding of the pilchard will enable the identification of this material to be carried much further.

(c) Ratio of phytoplantkon to zooplankton in stomach contents.

Having established that the pilchard feeds extensively on both phytoplankton and zooplankton it is of interest to ascertain the relative importance of these two planktonic groups in the feeding of the pilchard. If it were established that the pilchard showed a marked preference for a particular group it is possible that this preference could influence the movement of pilchard shoals in relation to food supply.

From June, 1953, to December, 1956, the proportions of phytoplankton to zooplankton in pilchard stomachs were calculated on a monthly basis (see Table 6) and illustrated by means of histograms (see Plate 14).

The mean ratio of phytoplankton to zooplankton for the whole period was then calculated (see Table 6) and illustrated graphically (see Plate 15).

The relationship between phytoplankton and zooplankton recorded in stomach contents on a seasonal basis was as follows:—

Summer.

(No data obtained for December due to the absence of pilchards in the area.) During January the zooplankton content of pilchard stomachs was 24 per cent higher than the phytoplankton content. This position had become reversed by February, however, when the phytoplankton recorded was 22 per cent higher than the zooplankton.

Autumn.

During autumn, phytoplankton (mean composition in stomach contents for the season 73 per cent) was recorded in the stomach contents of pilchards to an extent of almost three times the quantity of zooplankton (mean composition 27 per cent).

Winter.

In June, the first month of winter, phytoplankton was recorded in pilchard stomachs to an extent of almost twice the quantity of zooplankton. By mid-winter, however, the amount of zooplankton recorded had undergone a rapid increase to reach nearly twice the volume of phytoplankton. In August, the amount of zooplankton had again fallen to approximately one third of the phytoplankton recorded.

Spring.

During September and October phytoplankton was recorded in pilchard stomachs in far greater quantity than zooplankton which reached a minimum for the year at this time.

In November, however, the amount of phytoplankton decreased and the quantity of zooplankton increased with the result that the amounts recorded became almost equal.

From these data it is evident that *during the greater part of the year phytoplankton features in the stomach contents of pilchards to a far greater extent than zooplankton. The mean ratio for the year of phytoplankton to zooplankton was calculated to be* 66: 34, *i.e. nearly* 2: 1 *by volume.*

The inverse relationship between the phytoplankton and the zooplankton recorded in pilchard stomachs throughout the year is most marked (see Plate 15) and may be briefly stated as follows:— *When large quantities of phytoplankton are consumed by pilchards, e.g. in autumn and spring, comparatively small amounts of zooplankton are found in their stomach contents and when large amounts of zooplankton are recorded, e.g. in summer and winter, the quantity of phytoplankton eaten is diminished.*

It is possible that this ratio may to some extent be effected by the slower rate of digestion of phytoplanktonic organisms as compared with the more important zooplanktonic forms such as copepods. It is felt, however, that this could not alter the proportion a great deal.

It would appear, therefore, on the grounds stated above, that the pilchard does show a preference—and a very marked one—for phytoplankton. In order to make certain, however, consideration of two other factors is necessary. These factors are, firstly, the method by which the pilchard feeds and secondly, the relative availability of phytoplankton and zooplankton.

The method of feeding of the pilchard is discussed in this section and the question of the availability of plankton in the following section [see Section 4 (*d*)].

The pilchard is equipped, from an anatomical point of view, as a plankton feeder. Like the California sardine, *Sardina caerulea* (Scofield, 1934), the South African pilchard possesses gill-rakers each with two rows of lateral processes which form a very fine filtering structure capable of withholding minute organisms. *On anatomicol grounds therefore there is no doubt that the pilchard is primarily a filter feeder on plankton.*

Adult pilchards have been kept alive in the aquarium attached to the Division of Fisheries for many months. From observations on these fish there is also no doubt that the pilchard, in addition to being a filter feeder, may also be a particulate feeder. Small numbers of brine-shrimp (*Artemia salina*), amphipods and large fragments of a prepared fish food introduced into the aquarium tank caused pilchards to swim actively after and swallow large individual organisms or objects. *The pilchard is therefore mainly a filter feeder on plankton but may at times be a particulate feeder.*

The problem of whether the pilchard is normally a selective feeder will be considered after the next section when the relationship between the food of the pilchard and the availablility of plankton has been discussed.

(d) Relationship between the plankton in stomach contents and the plankton in the sea.

The relationship between the abundance of pilchards in the St. Helena Bay area and plankton has already received consideration (de Jager, 1954 and Davies, 1956 *b*). It was found that during the period March to August when pilchards are most abundant in the St. Helena Bay area, plankton abundance undergoes a steady decline. This was attributed to a combination of the feeding activities of the pilchards and the decrease in the availability of nutrient materials following a seasonal reduction in the amount of upwelling.

A comparison was made and illustrated graphically (see Plate 16) of the mean monthly figures for phytoplankton recorded in the stomachs of pilchards over the period 1953–56 (see Table 6) and the phytoplankton recorded in the area in which the pilchards were caught, viz. the St. Helena Bay area. The latter data were obtained from the mean figures for phytoplankton abundance based on diatom, etc., counts for the years 1954–55 (Davies, 1956 *b*).

There is a direct relationship between the phytoplankton recorded in pilchard stomachs and the phytoplankton recorded in the commercial fishing area during most months of the year. This is clearly shown by the similar trend of the two graphs (see Plate 16).

From January when the pilchards begin their return to the St. Helena Bay area their consumption

of phytoplankton increases through to March in spite of a marked fall in available phytoplankton in February. By March pilchards are usually abundant in the area and the graph of the amount of phytoplankton consumed follows the trend of the curve of the phytoplankton in the surrounding sea very closely through to October, by which time the pilchard shoals have begun their departure.

It is evident therefore that pilchards in the St. Helena Bay area feed heavily on phytoplankton in a manner which varies according to its availability in the area.

A further comparison was made and illustrated graphically (see Plate 17) of the mean monthly figures for zooplankton recorded in pilchard stomachs over the period 1953–56 (see Table 6) and the zooplankton recorded in the area in which the pilchards were caught. The latter data were obtained from the mean figures for zooplankton abundance based on the settled volumes of catches made with an N70 vertical plankton net (towed from 100–0 metres) operated at stations covering the commercial fishing area during the period 1952–55 (Davies, 1956 *b*).

Zooplankton is present in pilchard stomachs in large quantities in January when it is abundant in the plankton. While abundance of zooplankton in the sea increases in February and March, however, the quantities recorded in stomach contents decrease rapidly. From March through to July the amount of zooplankton in the sea declines rapidly while the zooplankton recorded in stomach contents increases at first steadily and then rapidly (from June) to reach a maximum for the year in July. From July the amount of zooplankton consumed falls sharply to reach a minimum consumption in October. Zooplankton volumes in the area meanwhile continue to decrease through to August and then increase from August through to October.

The relationship between the zooplankton recorded in pilchard stomachs and the zooplankton recorded in the commercial fishing area is to a large extent an inverse one (see Plate 17).

From the graphs (see Plates 16 and 17) it is seen that in July zooplankton was recorded in pilchard stomachs in maximum quantities when the phytoplankton available in the sea was at its lowest. When zooplankton in the sea was at its highest peak in March, it was recorded in pilchard stomachs in relatively small amounts due to the presence of sufficient phytoplankton in the sea.

According to these data therefore *the pilchards in the St. Helena Bay area feed on zooplankton in a manner which bears no direct relation to its availability.*

The pilchard is a filter feeder on plankton with the ability to feed in a particulate manner. In addition it feeds heavily on phytoplankton when available but does not necessarily feed heavily on zooplankton when it is available, provided that phytoplankton is present. On these grounds it would appear that *the pilchard shows a preference for phytoplankton in its diet.* By this it is not inferred that the pilchard carries out any kind of sorting process while feeding, although this may be possible to some extent by different arrangement of gillrakers. It is possible, however, that pilchards move from one area to another in which more suitable planktonic food is available, and their apparent preference for phytoplankton may well be exercised in this manner.

This apparent preference for phytoplankton as a food may be one of the main reasons for the congregation of the shoals in the St. Helena Bay area.

(e) State of repletion of pilchard stomachs.

The state of repletion or "fullness" of each pilchard stomach was examined in the course of the feeding studies. A full stomach was denoted by the figure 10, a stomach which was half filled by the figure 5 and so on.

Mean figures for the state of repletion of pilchard stomachs for each month for the period 1953–56 were tabulated (see Table 7).

From these figures it appears that *feeding activity is greater during the months January to March than during the remainder of the year. On a seasonal basis feeding remains at the same rather low level during autumn, winter and spring but is higher in summer.*

These figures are not considered to provide conclusive evidence concerning this aspect of the feeding activities of the pilchard, however, and should be taken as an indication only. Detailed studies of feeding in relation to the time of day, etc. may alter this assessment. A factor which may have considerable influence on the fullness of stomachs is that nearly all the commercial catches of pilchards are made at night. It is not known whether the South African pilchard favours day or night feeding, but a closely allied species *Sardinops melanosticta* is said to feed mainly during the day

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(Yoneda and Yoshida, 1955). If this were the case for the South African pilchard it would be important to make a special series of catches throughout the day for purposes of feeding studies.

5. General Discussion.

The gross feeding of the pilchard off the west coast of South Africa has been illustrated by means of a diagram (see Fig. 2), which shows that, on the basis of the available data, the pilchard feeds mainly on phytoplankton and to a lesser degree on zooplankton. The phytoplankton is made up of diatoms, dinoflagellates and unrecognisable phytoplankton and there is little doubt that the greater part of the unrecognisable phytoplankton consists of diatoms as well. In the same way the copepods make up the greater part of the zooplankton eaten and it is likely that they feature to a large extent in the unrecognisable zooplankton.

It is of interest to note that there is considerable similarity between the organisms eaten by the Cornish pilchard, *Sardina pilchardus* (Hickling, 1945) and the California sardine, *Sardina caerulea* (Anon., 1952). There is, however, considerable difference in the proportions in which the various groups are eaten.

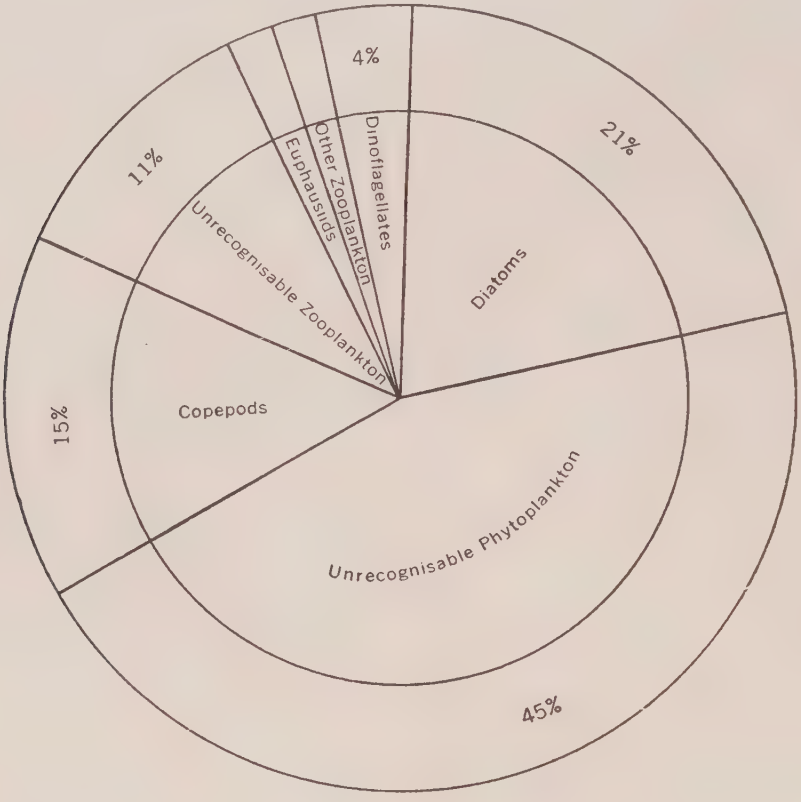

FIG. 2. THE FOOD OF THE SOUTH AFRICAN PILCHARD

A large quantity of accumulated data has been collected as the result of making plankton tow-net hauls (N50 vertical and N70 vertical nets towed from 100 to 0 metres or from 5 metres from the bottom to 0 metres) in the immediate vicinity of the positions where commercial boats were making their catches, and subsequently comparing the plankton with the stomach contents of the pil-

chards. A general examination of these data was made and there is no doubt that where recent feeding had taken place there was a marked correlation of the stomach contents with the plankton in the surrounding sea. On many occasions, however, feeding immediately prior to catching had not taken place and a comparison for purposes of correlation was not possible.

In spite of this evidence of correlation of stomach contents and plankton in the surrounding sea, phytoplankton is eaten in large quantities whenever it is available but zooplankton is eaten mainly when phytoplankton is scarce and the pilchard appears to favour phytoplankton in its feeding rather than zooplankton.

It should be borne in mind, however, that this report is of a preliminary nature and the findings are based on what might be termed a gross rather than a refined investigation.

In order to provide an accurate assessment of the feeding of the pilchard a far more detailed approach is considered necessary. Samples of pilchards should be specially caught and simultaneous samples of plankton taken at different times of the day in order to establish at what time of day the pilchard feeds most actively. Stomachs should be preserved immediately after catching in order to prevent further deterioration of their contents. In this manner better opportunities for the identification of quick digesting organisms such as copepods could be obtained. The entire contents of each stomach should be examined in detail and the food organisms accurately identified and counted. A system should be used whereby the relative size of the various organisms eaten is taken into consideration, for example, weighing and taking the volume of all members of each group found in the stomachs. Further, the relative nutritional value of the main groups eaten could be established by means of chemical analysis.

It is hoped that it will be possible to undertake a more detailed study of the feeding of the pilchard.

6. Acknowledgments.

I am much indebted to Dr. J. M. Marchand, Director of Fisheries, and my colleagues of the Division of Fisheries, for reading and criticising this paper.

I wish to acknowledge the field work of sample examination carried out by Messrs. B. de Jager, C. Nepgen, K. van Rensburg, A. Heydorn, R. van Zyl and D. van Schoor, all of this Division, and the assistance given by Messrs. D. van Schoor and M. Thomson, late of this Division.

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Table 1.

Percentage Composition of the Stomach Contents of Pilchards, 1953.

1953. Month.	Diatoms.	*Dinoflagellata.*	Unrecognisable Phytoplankton.	*Protozoa.*	*Copepoda.*		*Euphausiacea.*		Unrecognisable Zooplankton.	Other *Crustacea.*		Fish eggs and larvae.	*Amphipoda.*	*Chaetognatha.*	*Ostracoda.*	*Mollusca.*	Other Zooplankton.
					Eggs or larvae.	Adults.	Eggs or larvae.	Adults.		Eggs or larvae.	Adults.						
June (600)*.....	31	16	9	1	<1	42	—	—	—	—	—	<1	—	—	—	<1	—
July (525)*.....	70	6	1	—	1	20	—	—	1	—	—	—	<1	—	—	<1	<1 *Cladocera.*
August (450)*.....	36	12	8	—	—	20	—	7	11	—	—	—	—	4	—	1	1 *Cladocera.*
September (450)*.....	64	6	14	—	—	12	3	—	—	<1	—	—	—	—	—	—	<1 *Stomatopoda.*
October (81)*.....	6	—	84	—	—	8	—	<1	—	1	—	—	—	—	<1	—	—
November (0)*.....	No samples obtained.																
December (0)*.....	No samples obtained.																

* Numbers in brackets indicate numbers of fish examined.

TABLE 2.

PERCENTAGE COMPOSITION OF THE STOMACH CONTENTS OF PILCHARDS, 1954.

1954. Month.	Diatoms.	*Dinoflagellata.*	Unrecognisable Phytoplankton.	*Protozoa.*	*Copepoda.*		*Euphausiacea.*		Unrecognisable Zooplankton.	Other *Crustacea.*		Fish eggs and larvae.	*Amphipoda.*	*Chaetognatha.*	*Ostracoda.*	*Mollusca.*	Other Zooplankton.
					Eggs or larvae.	Adults.	Eggs or larvae.	Adults.		Eggs or larvae.	Adults.						
January (300)*	17	9	14	—	—	59	—	—	—	—	—	—	—	—	—	1	—
February (200)*	80	7	—	—	1	10	—	1	—	—	—	—	—	—	<1	—	<1 *Stomatopoda.*
March (300)*	68	5	—	—	—	18	—	—	8	—	—	—	<1	—	—	—	—
April (350)*	13	13	41	—	—	9	<1	1	21	<1	—	—	—	1	<1	<1	—
May (849)*	10	2	43	—	<1	5	—	<1	37	1	—	<1	<1	—	<1	1	—
June (550)*	17	2	55	<1	<1	9	—	—	15	1	—	—	—	—	<1	<1	—
July (300)*	1	1	1	—	—	2	—	10	84	—	—	<1	—	—	<1	<1	<1 *Gastropoda*
August (176)*	8	1	83	1	—	5	1	—	—	—	—	—	—	—	—	<	1 Shell remains.
September (179)*	32	1	66	—	—	—	—	—	—	—	—	—	—	—	—	—	—
October (431)*	9	2	87	—	<1	1	—	—	—	—	—	—	—	—	<1	<1	<1 *Zoea* Crab.
November (150)*	—	1	96	—	—	1	—	—	3	—	—	—	—	—	1	—	—
December (0)*	No samples obtained.																

* Numbers in brackets indicate numbers of fish examined.

Table 3.

Percentage Composition of the Stomach Contents of pilchards, 1955.

1955. Month.	Diatoms.	*Dinoflagellata.*	Unrecognisable Phytoplankton.	*Protozoa.*	*Copepoda.*		*Euphausiacea.*		Unrecognisable Zooplankton.	Other *Crustacea.*		Fish eggs and larvae.	*Amphipoda.*	*Chaetognatha.*	*Ostracoda*	*Mollusca.*
					Eggs or larvae.	Adults.	Eggs or larvae.	Adults.		Eggs or larvae.	Adults.					
January (0)*	No samples obtained.															
February (450)*	32	7	51	—	—	1	<1	—	8	—	—	—	—	—	—	
March (1,600)*	11	2	79	—	—	3	<1	—	5	—	—	—	—	—	<1	—
April (350)*	12	4	52	—	—	11	—	—	21	—	—	—	—	—	—	—
May (350)*	1	3	64	—	—	7	<1	—	21	—	—	—	—	3	—	—
June (600)*	10	2	52	—	—	13	1	—	21	—	—	<1	—	—	<1	<1
July (500)*	4	<1	19	—	<1	16	<1	—	58	<1	—	<1	<1	—	—	1
August (950)*	26	3	46	<1	<1	6	—	—	16	<1	—	1	<1	<1	—	<1
September (1,200)*	35	1	49	—	—	7	<1	—	5	—	—	3	<1	<1	—	—
October (50)*	70	10	5	—	—	—	10	—	5	—	—	—	—	—	—	—
November (50)*	10	—	5	—	—	10	60	—	—	—	—	—	—	—	—	15
December (0)*	No samples obtained.															

* Numbers in brackets indicate numbers of fish examined.

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Table 4.

Percentage Composition of the Stomach Contents of Pilchards, 1956.

1956. Month.	Diatoms.	*Dinoflagellata.*	Unrecognisable Phytoplankton.	*Protozoa.*	*Copepoda.*		*Euphausiacea.*		*Cladocera.*	Other *Crustacea.*		*Chaetognatha.*	Fish eggs and larvae.	Unrecognisable Zooplankton.	*Ostracoda.*	*Amphipoda.*	*Mollusca.*	Other Zooplankton.
					Eggs or larvae.	Adults.	Eggs or larvae.	Adults.		Eggs or larvae.	Adults.							
January..... (400)*	32	<1	3	—	<1	60	—	<1	<1	—	—	—	<1	3	1	<1	1	—
February..... (100)*	3	—	2	—	—	72	—	—	—	3	—	—	—	19	—	—	—	—
March..... (1,100)*	13	8	48	—	<1	18	<1	1	—	—	—	—	—	10	<1	<1	<1	—
April..... (650)*	11	7	59	3	1	11	<1	—	—	<1	—	<1	—	7	—	<1	—	—
May..... (200)*	11	9	64	1	1	7	—	—	—	<1	—	<1	—	5	—	—	—	—
June..... (0)*	No samples obtained.																	
July..... (573)*	12	1	26	<1	<1	41	—	1	—	1	—	1	1	15	—	<1	—	—
August..... (700)*	26	1	55	<1	<1	8	<1	—	—	1	—	<1	<1	8	<1	<1	—	<1 *Stomatopoda.*
September... (550)*	32	2	55	<1	—	4	<1	—	—	<1	—	<1	1	4	<1	<1	—	<1 *Cephalopoda.*
October..... (400)*	11	1	84	—	—	1	—	—	—	—	—	<1	<1	2	—	—	<1	—
November... (0)*	No samples obtained.																	
December.... (0)*	No samples obtained.																	

* Numbers in brackets indicate numbers of fish examined.

TABLE 5.—MEAN PERCENTAGE COMPOSITION OF THE STOMACH CONTENTS OF PILCHARD SAMPLES, 1953–56.

Month.	PHYTOPLANKTON.			ZOOPLANKTON.													
	Diatoms.	*Dinoflagellata.*	Unrecognisable Phytoplankton.	*Protozoa.*	*Copepoda.* Eggs or larvae.	*Copepoda.* Adults.	*Euphausiacea.* Eggs or larvae.	*Euphausiacea.* Adults.	Unrecognisable Zooplankton.	Other *Crustacea.* Eggs or larvae.	Other *Crustacea.* Adults.	Fish eggs and larvae.	*Amphipoda.*	*Chaetognatha.*	*Ostracoda.*	*Mollusca.*	Other Zooplankton.
January (2)*.....	25	4	8	—	<1	59	—	<1	2	—	—	<1	<1	—	1	1	<1 *Cladocera.*
February (3)*.....	41	6	31	—	<1	13	<1	<1	8	<1	—	—	—	—	<1	—	<1 *Stomatopoda.*
March (3)*.....	17	4	60	—	<1	10	<1	<1	7	—	—	—	<1	—	<1	<1	—
April (3)*.....	12	8	53	1	<1	10	<1	<1	14	<1	—	—	<1	<1	<1	<1	—
May (3)*.....	8	3	52	<1	<1	5	<1	<1	29	<1	—	<1	<1	1	<1	1	<1 Barnacle larvae.
June (3)*.....	19	7	38	<1	<1	22	<1	—	12	<1	—	<1	—	—	<1	<1	—
July (4)*.....	25	2	13	<1	<1	23	<1	2	33	<1	—	<1	<1	<1	<1	<1	<1 *Zoea* <1 *Gastropoda.* <1 *Cladocera.*
August (4)*.....	26	4	45	<1	<1	9	<1	1	11	<1	—	<1	<1	1	<1	<1	<1 *Cladocera.* <1 *Stomatopoda.* <1 Shell remains. <1 *Zoea* <1 Barnacle larvae.
September (4)*.....	39	2	46	<1	—	6	1	—	3	<1	—	1	<1	<1	<1	—	<1 *Stomatopoda.* <1 Barnacle larvae. 1 Squid juvenile.
October (4)*.....	12	2	82	—	<1	2	<1	<1	1	<1	—	<1	—	<1	<1	<1	—
November (2)*.....	2	<1	72	—	—	3	15	—	2	—	—	—	—	—	<1	4	—
December (0)*.....	No samples obtained.																
Mean.....	21	4	45	<1	<1	15	2	<1	11	<1	—	<1	<1	<1	<1	1	<1

* Numbers in brackets indicate numbers of fish examined.

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Table 6.

Percentage Composition in relation to Phytoplankton and Zooplankton of the Stomach Contents of Pilchards, 1953–56.

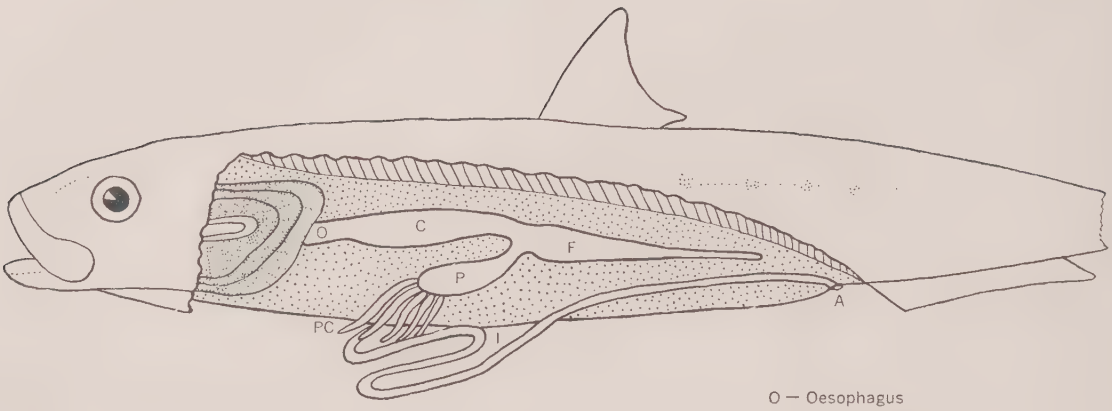
Month.	1953.		1954.		1955.		1956.		1953–1956.	
	Total Phyto-plankton.	Total Zooplank-ton.	Total Phyto-plankton.	Total Zooplank-ton.	Total Phyto-plankton.	Total Zooplank-ton.	Total Phyto-plankton.	Total Zooplank-ton.	Total Phyto-plankton.	Total Zooplank-ton.
January	—	—	40	60	No samples obtained.		35	65	38	62
February	—	—	87	13	90	10	5	95	61	39
March	—	—	73	27	92	8	69	31	78	22
April	—	—	67	33	68	32	77	23	71	29
May	—	—	55	45	68	32	84	16	69	31
June	56	44	74	26	64	36	No samples obtained.		65	35
July	77	23	3	97	23	77	39	61	36	64
August	56	44	92	8	75	25	82	18	76	24
September	84	16	100	0	85	15	89	11	90	10
October	90	10	98	2	85	15	96	4	92	8
November	No samples obtained.		95	5	15	85	No samples obtained.		55	45
December	No samples obtained.		No samples obtained.		No samples obtained.		No samples obtained.		—	—
								Mean.....	66	34

TABLE 7.

MEAN STATE OF REPLETION* OF PILCHARD STOMACHS, 1953–56.

Month.	1953.	1954.	1955.	1956.	Mean 1953–56.	Seasonal Mean.	
January	8	3	—	4	6	5	Summer.
February	7	5	2	6	4		
March	9	5	3	4	5	3	Autumn.
April	4	1	5	2	3		
May	4	2	1	2	2		
June	5	3	1	—	3	3	Winter.
July	5	0	2	2	2		
August	3	1	4	3	3		
September	3	4	5	2	4	3	Spring.
October	5	1	4	2	3		
November	1	4	4	—	3		
December	—	—	—	—	—	—	

* A full stomach is denoted by the figure 10.



O — Oesophagus

C — Cardiac Stomach

P — Pyloric Stomach

F — Fundus of Stomach

I — Intestine

PC — Pyloric Caeca

A — Anus

PLATE 1. DIAGRAMMATIC REPRESENTATION OF THE ALIMENTARY SYSTEM OF THE PILCHARD

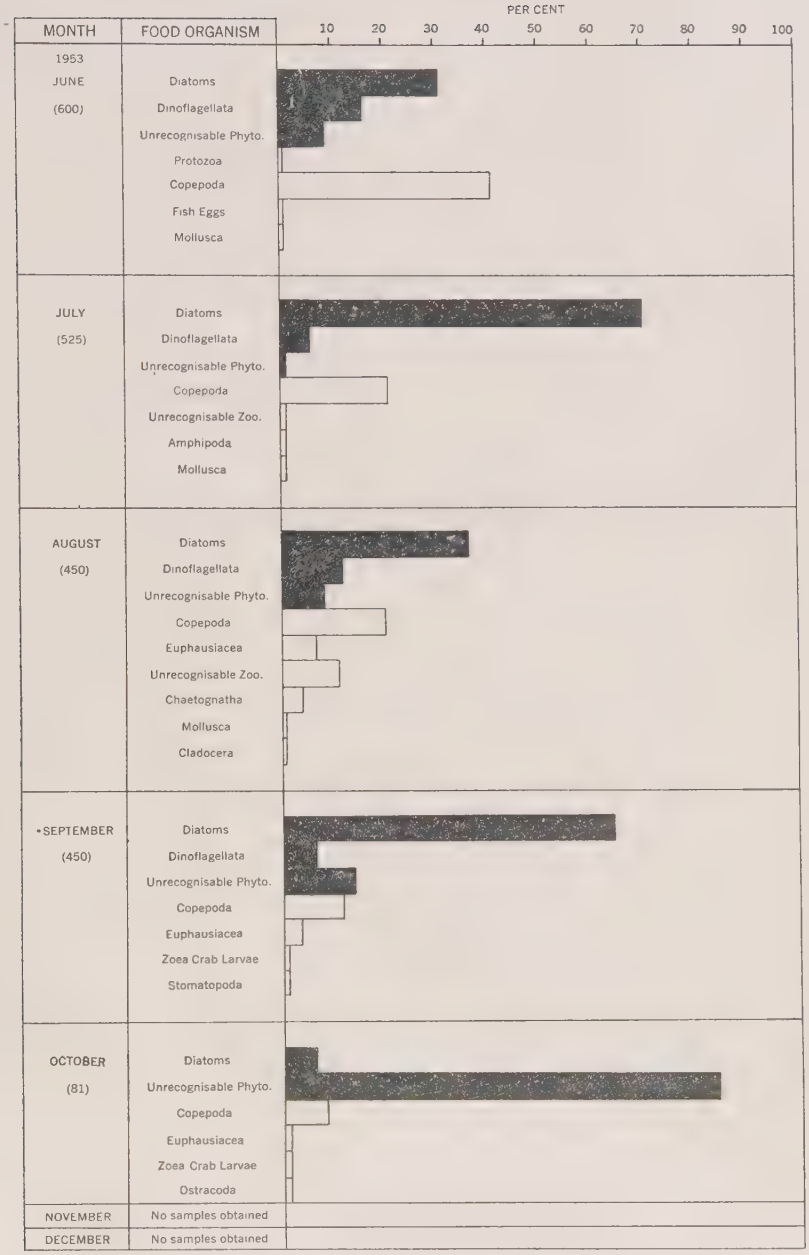


PLATE 2. MONTHLY VARIATION OF THE FOOD OF THE PILCHARD, 1953.

Trigsurvey, 1957. Government Printer, 1957.

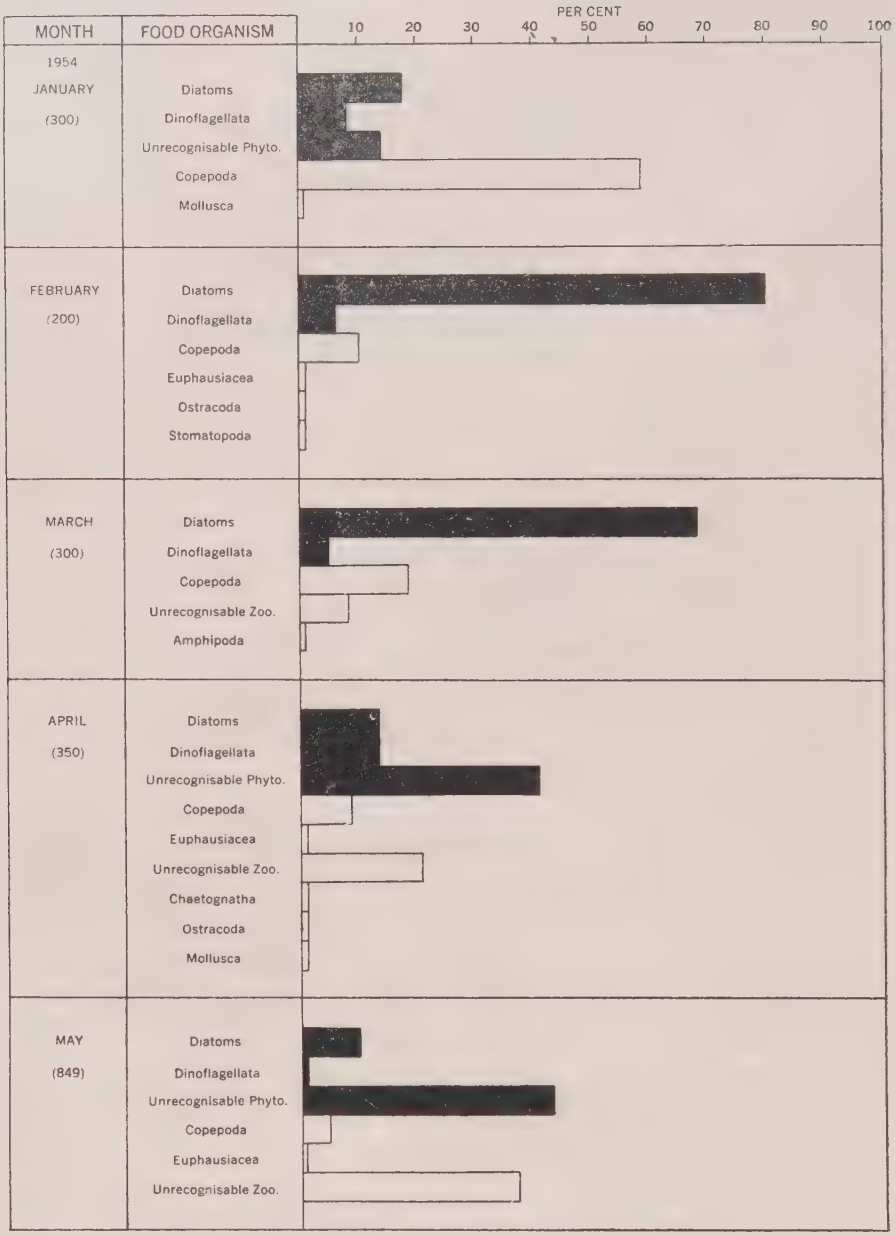


PLATE 3. MONTHLY VARIATION OF THE FOOD OF THE PILCHARD 1954

Trigsurvey, 1957. Government Printer, 1957.

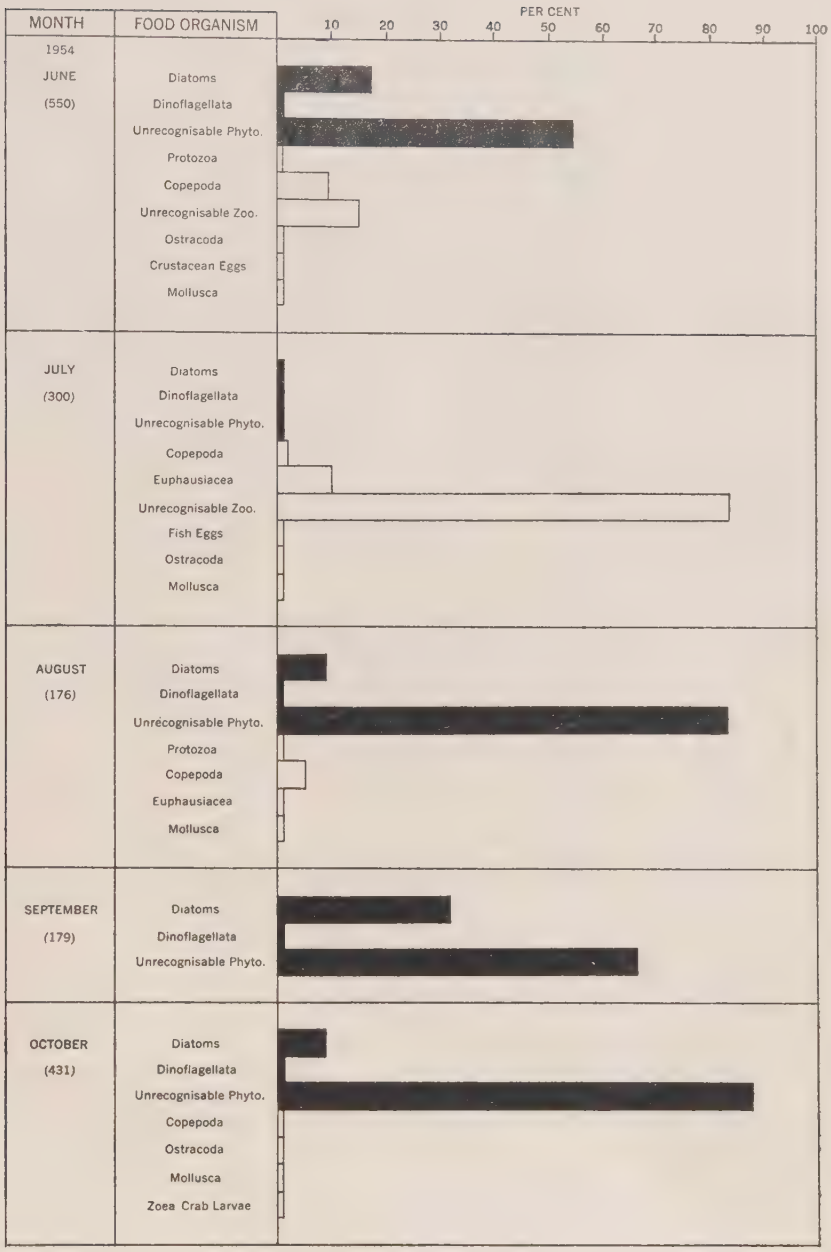


PLATE 4. MONTHLY VARIATION OF THE FOOD OF THE PILCHARD, 1954.

Trigsurvey, 1957. Government Printer, 1957.

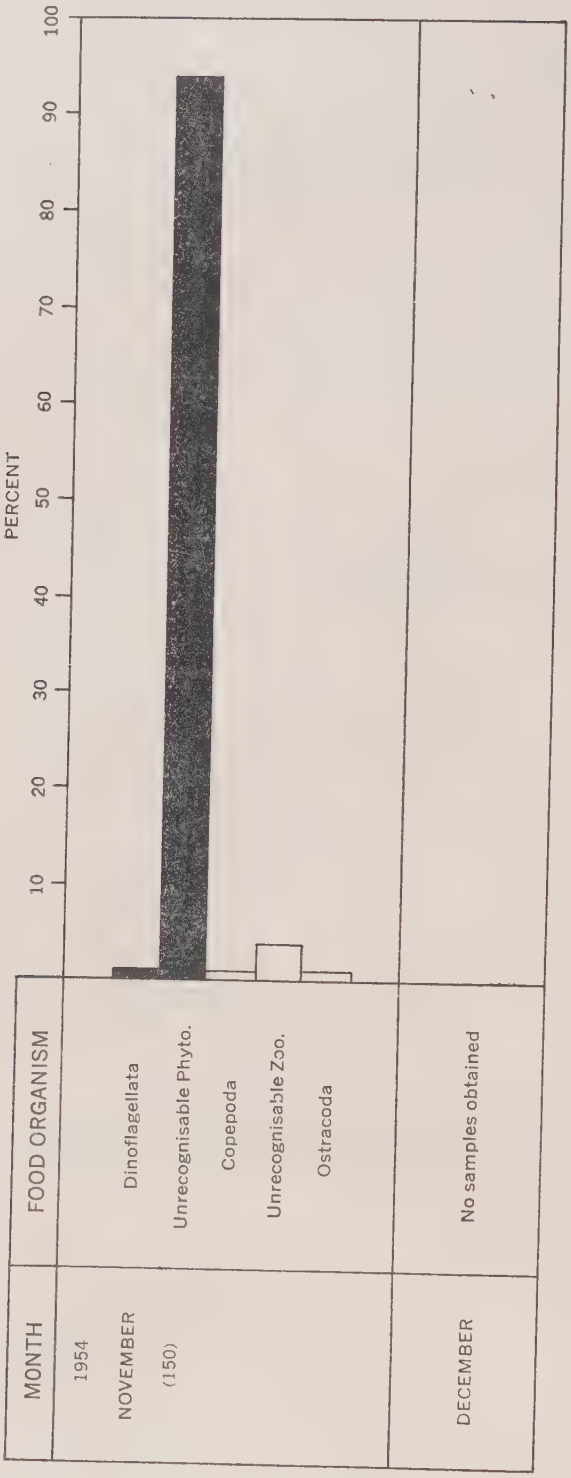


PLATE 5. MONTHLY VARIATION OF THE FOOD OF THE PILCHARD, 1954

Trigsurvey, 1957.

Government Printer, 1957.

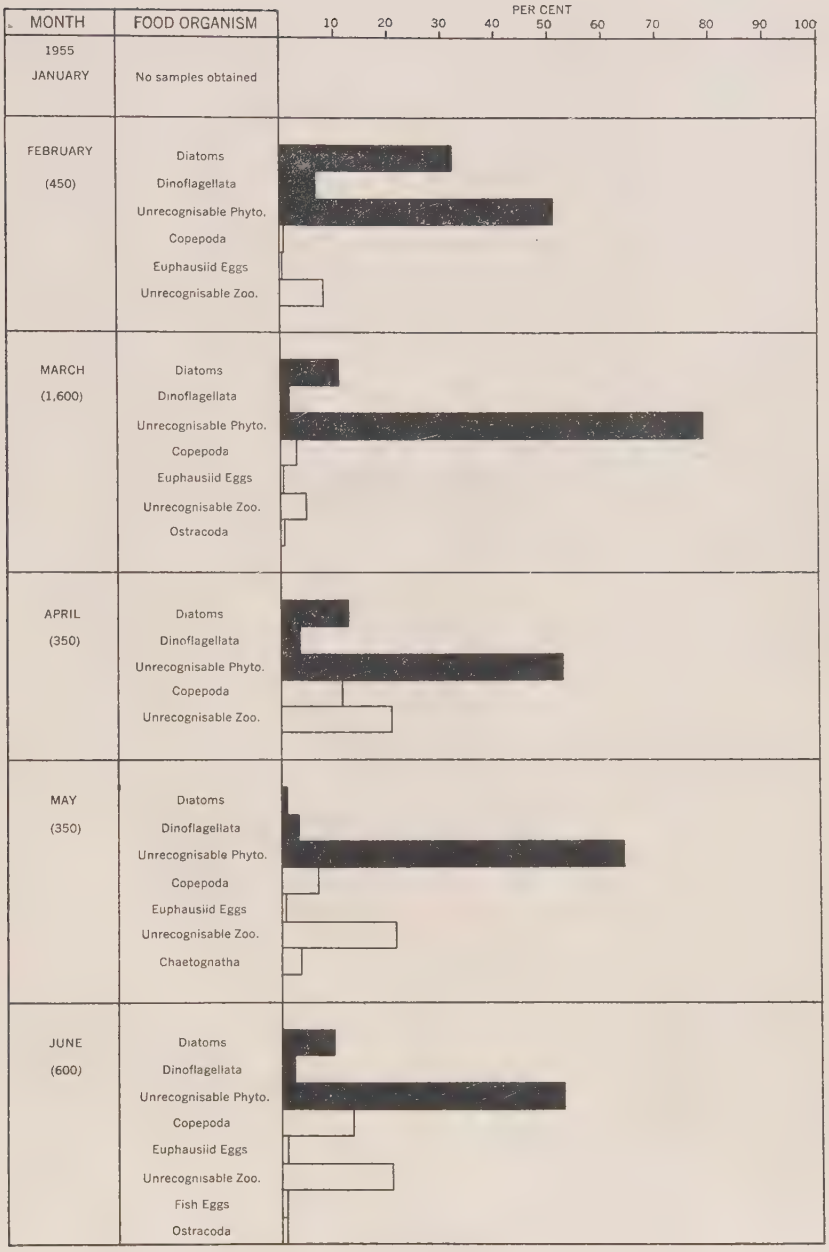


PLATE 6 MONTHLY VARIATION OF THE FOOD OF THE PILCHARD, 1955.

Trigsurvey, 1957. Government Printer, 1957.

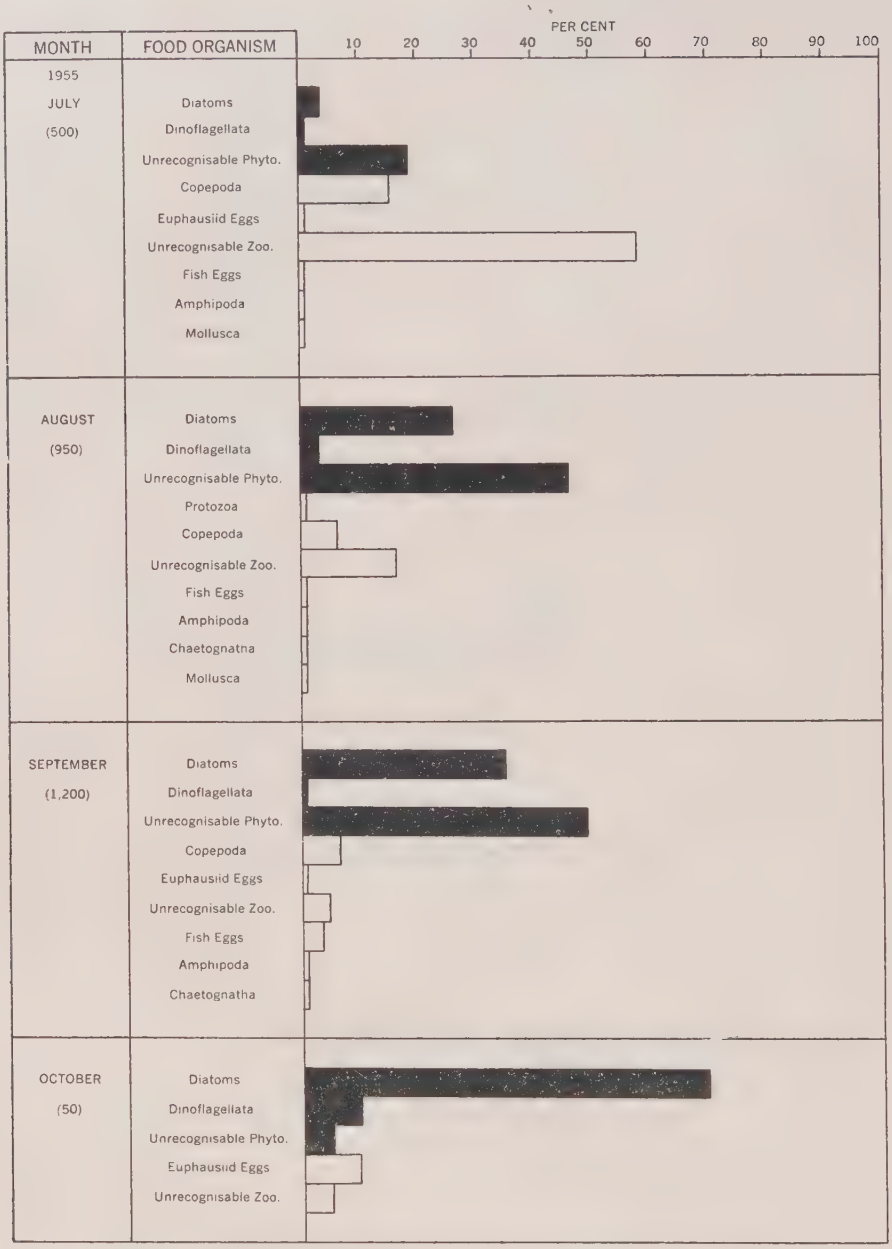


PLATE 7 MONTHLY VARIATION OF THE FOOD OF THE PILCHARD, 1955.

Trigsurvey, 1957. Government Printer, 1957.

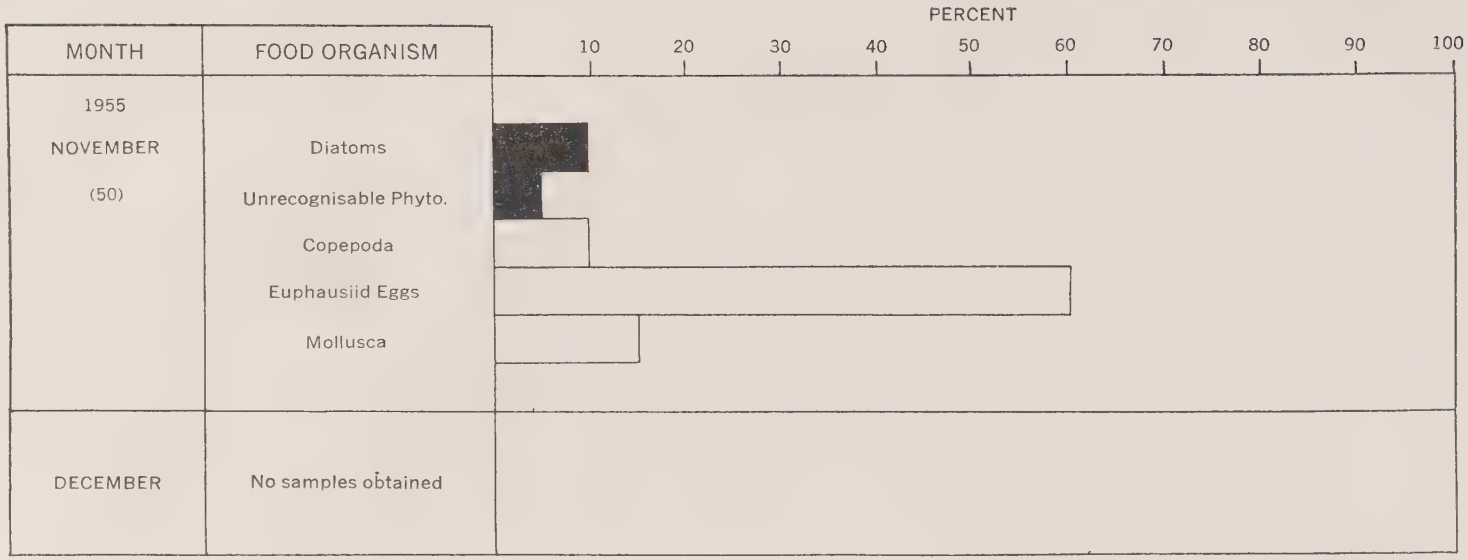


PLATE 8. MONTHLY VARIATION OF THE FOOD OF THE PILCHARD, 1955

Trigsurvey, 1957.

Government Printer, 1957.

Reprint from "Commerce & Industry", November, 1957

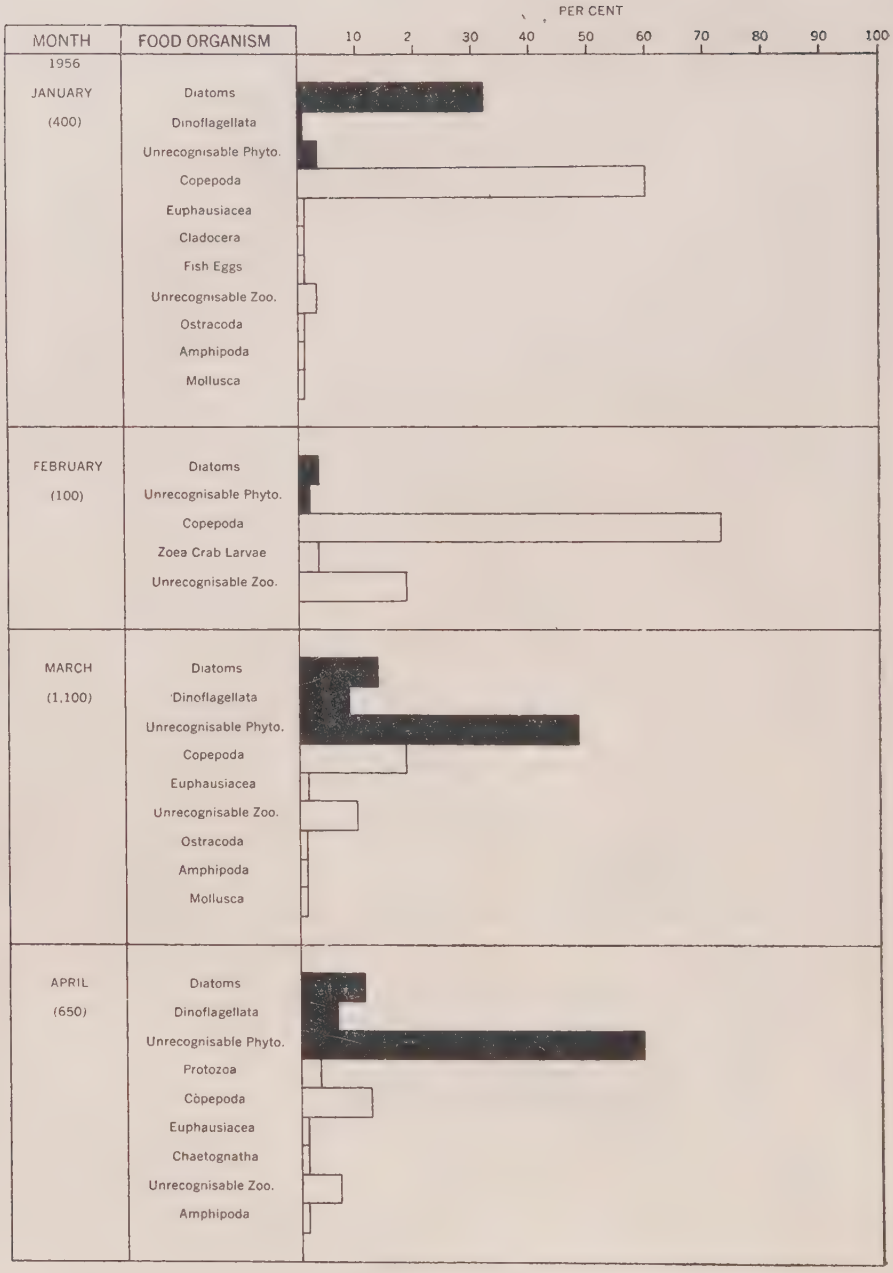


PLATE 9 MONTHLY VARIATION OF THE FOOD OF THE PILCHARD, 1956.

Trigsurvey, 1957

Government Printer, 1957

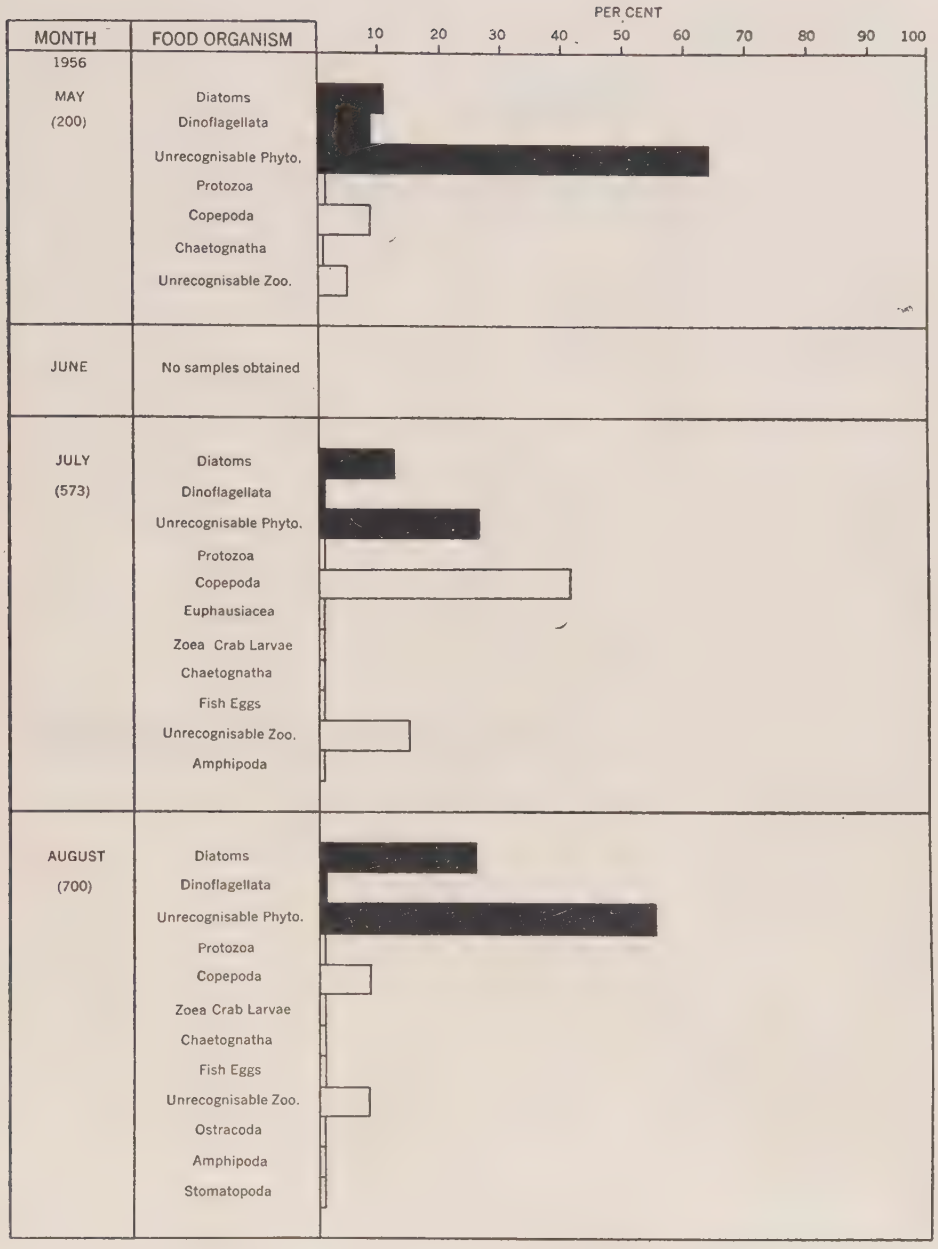


PLATE 10. MONTHLY VARIATION OF THE FOOD OF THE PILCHARD, 1956.

Trigsurvey, 1957. Government Printer, 1957.

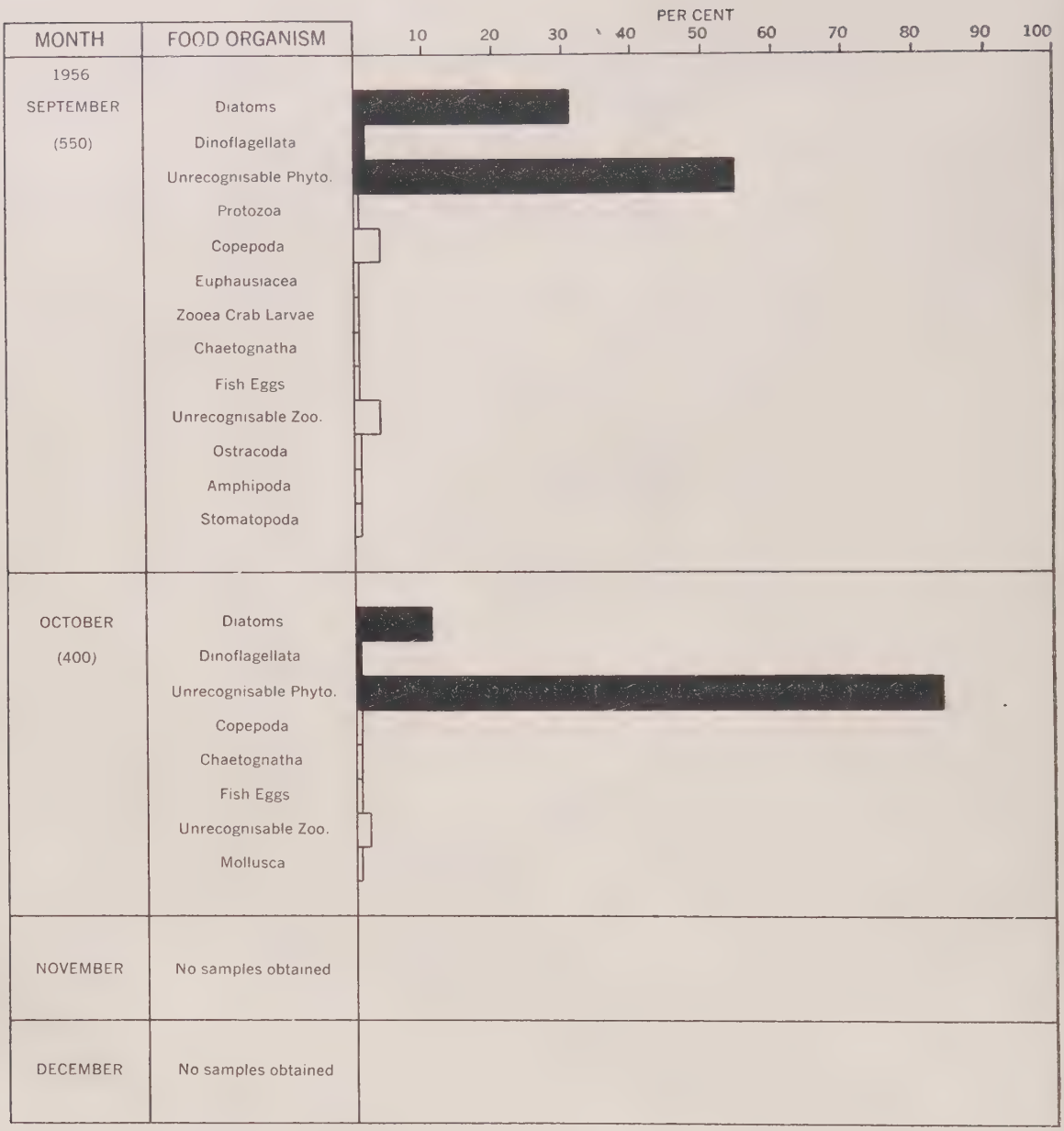


PLATE 11. MONTHLY VARIATION OF THE FOOD OF THE PILCHARD, 1956.

Trigsurvey, 1957. Government Printer, 1957.

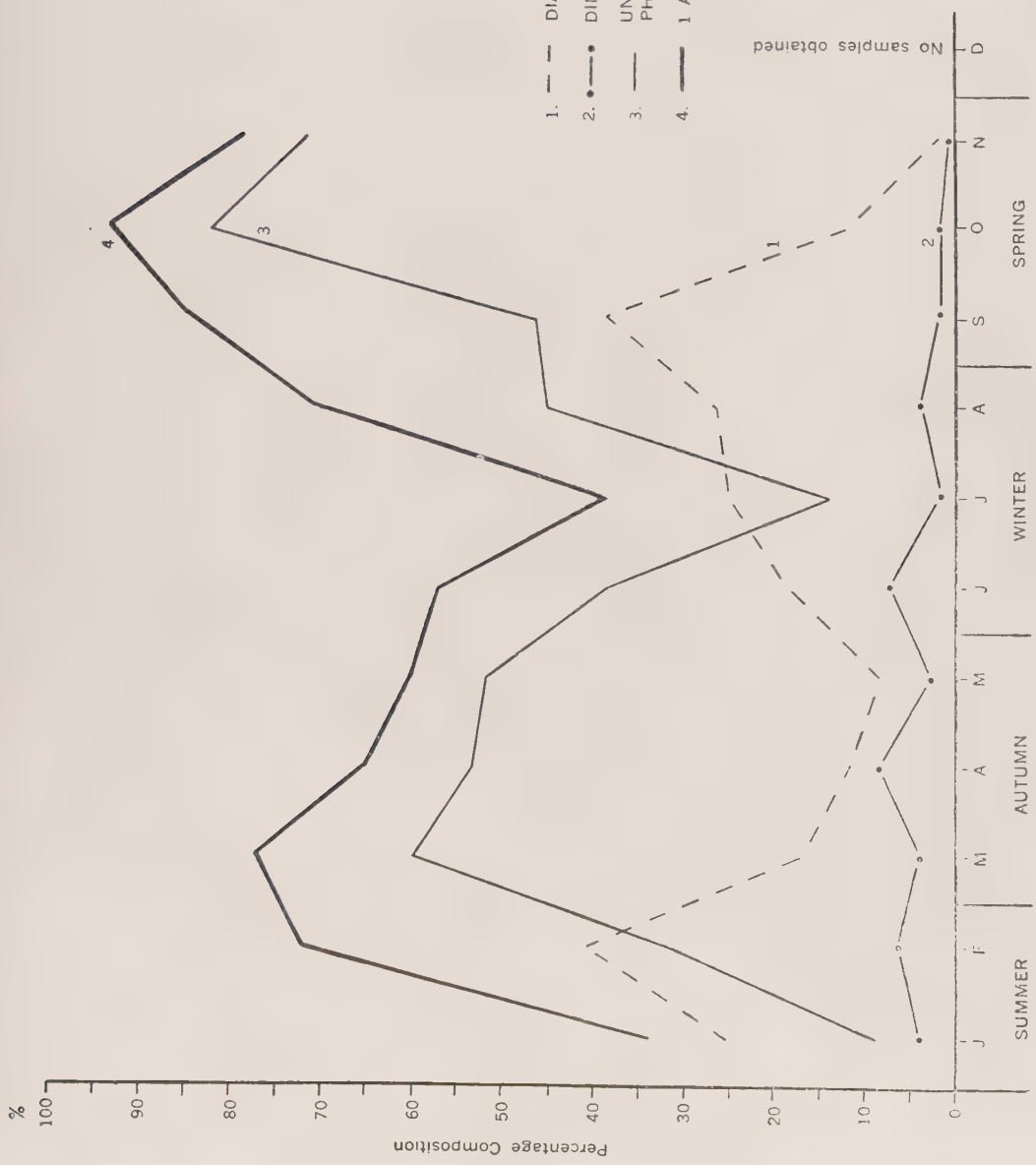


PLATE 12. MEAN MONTHLY PHYTOPLANKTON CONTENT IN PILCHARD STOMACHS, 1953–56.

PLATE 13. MEAN MONTHLY STOMACH CONTENT OF MAIN GROUPS IN THE ZOOPLANKTON, 1953–56.

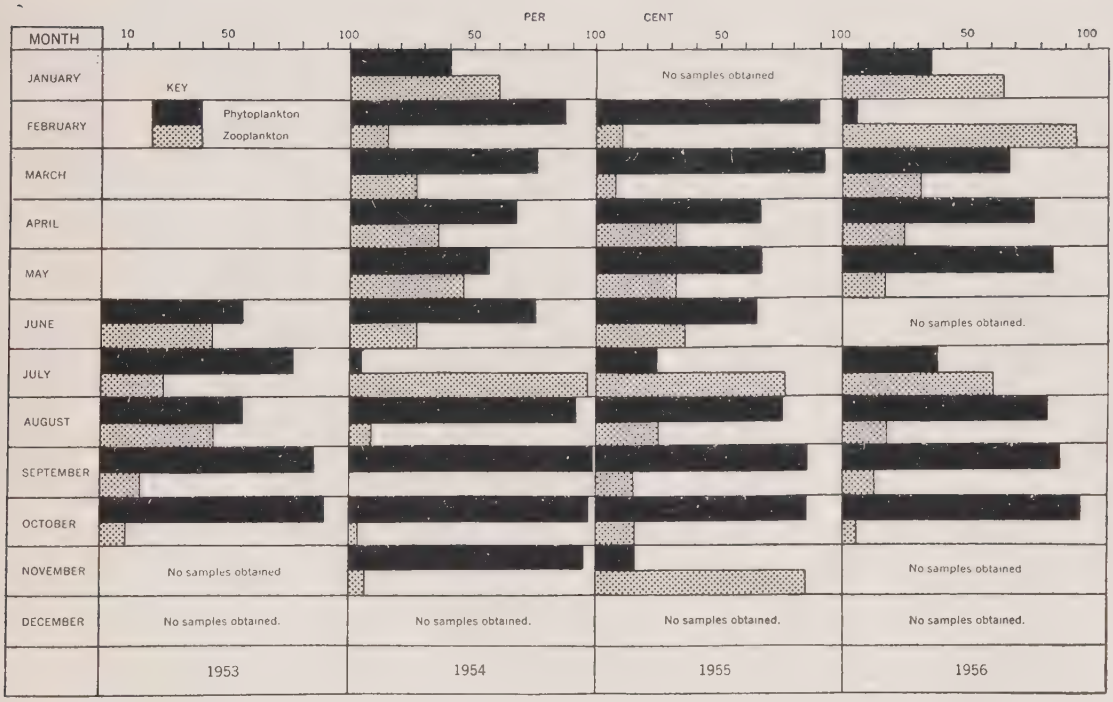


PLATE 14. PERCENTAGE COMPOSITION OF PHYTOPLANKTON AND ZOOPLANKTON IN PILCHARD STOMACHS, 1953-56.

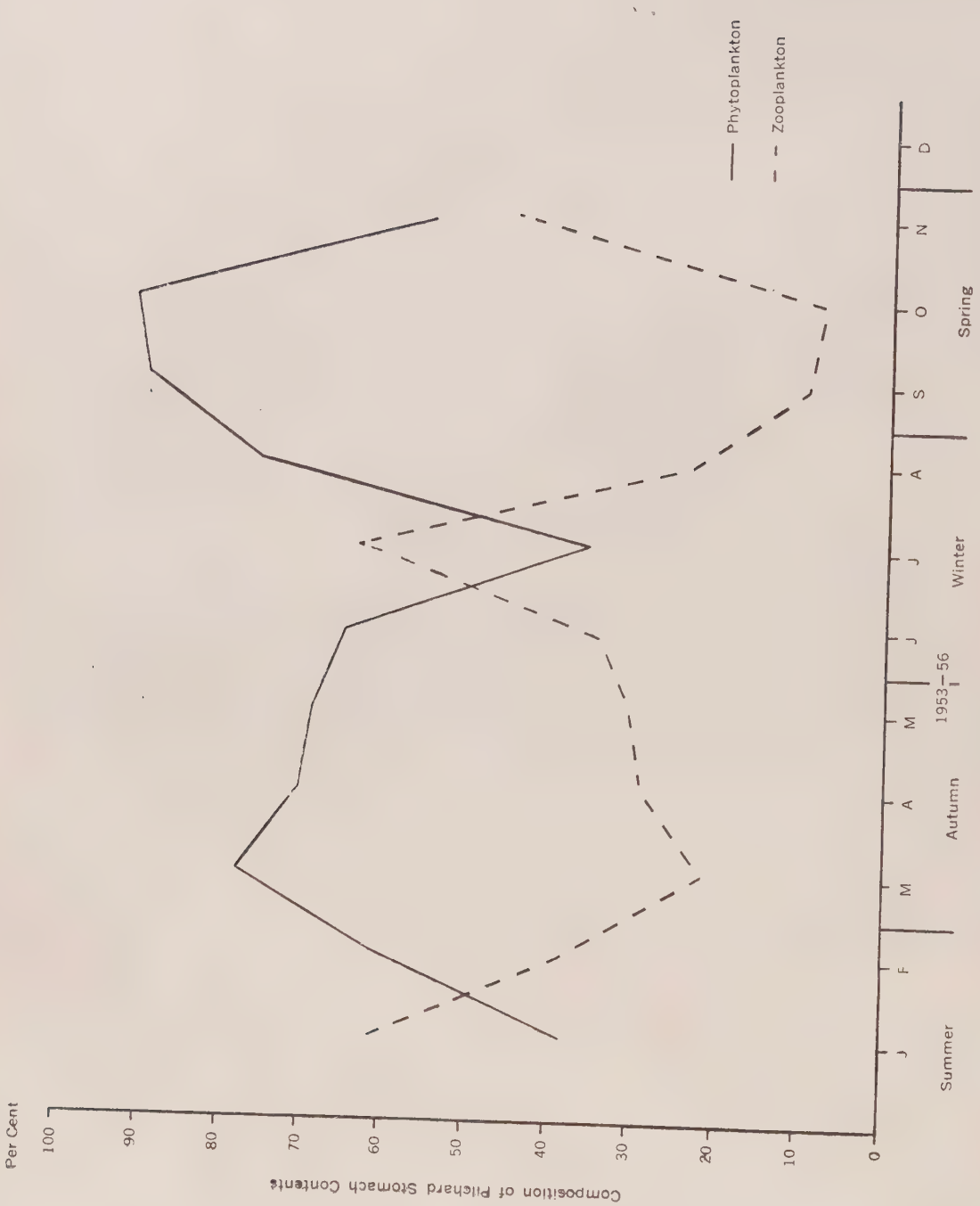


PLATE 15. THE RATIO OF PHYTOPLANKTON TO ZOOPLANKTON IN PILCHARD STOMACH CONTENTS

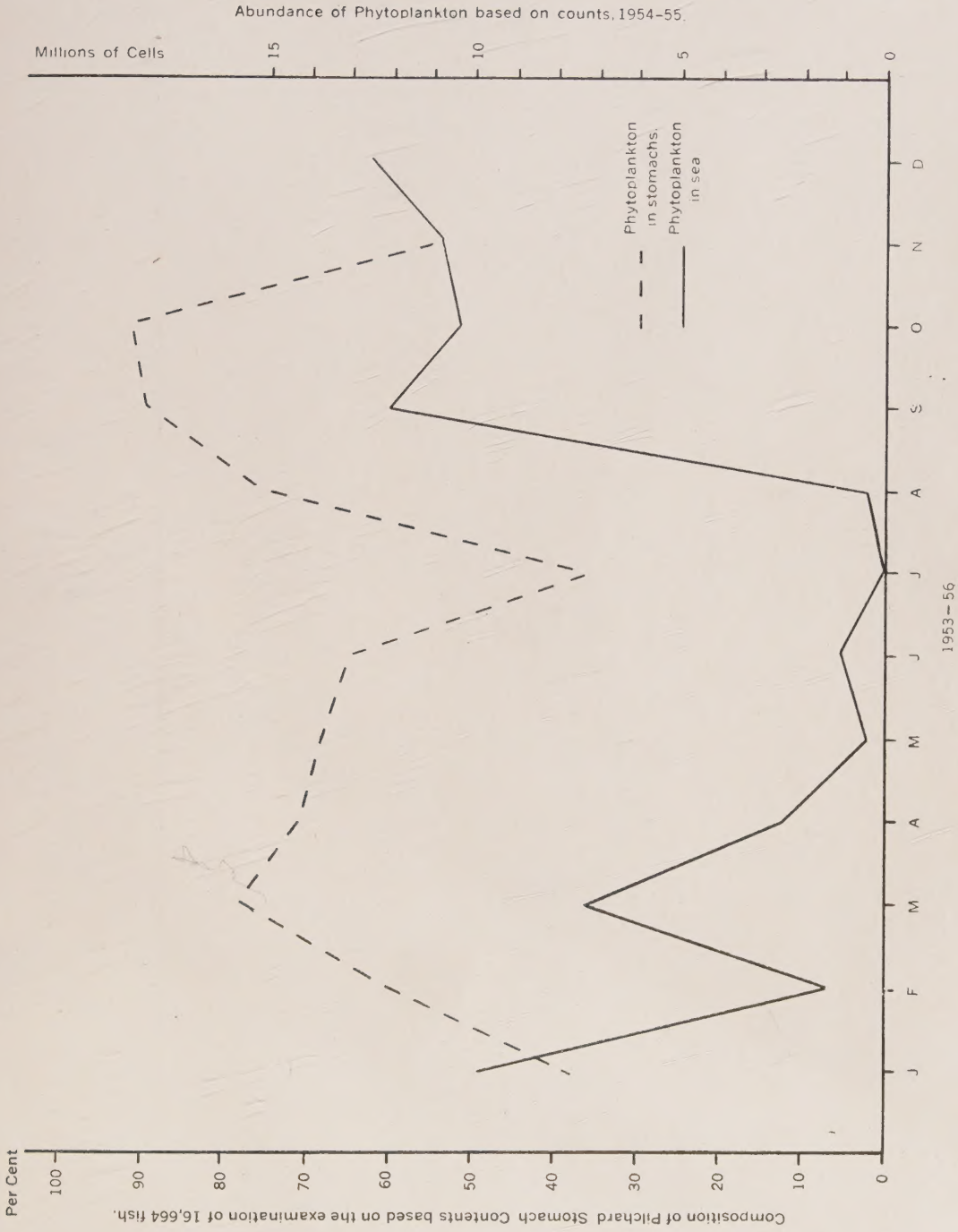


PLATE 16. THE RELATIONSHIP BETWEEN THE PHYTOPLANKTON IN PILCHARD STOMACH CONTENTS AND IN THE SEA

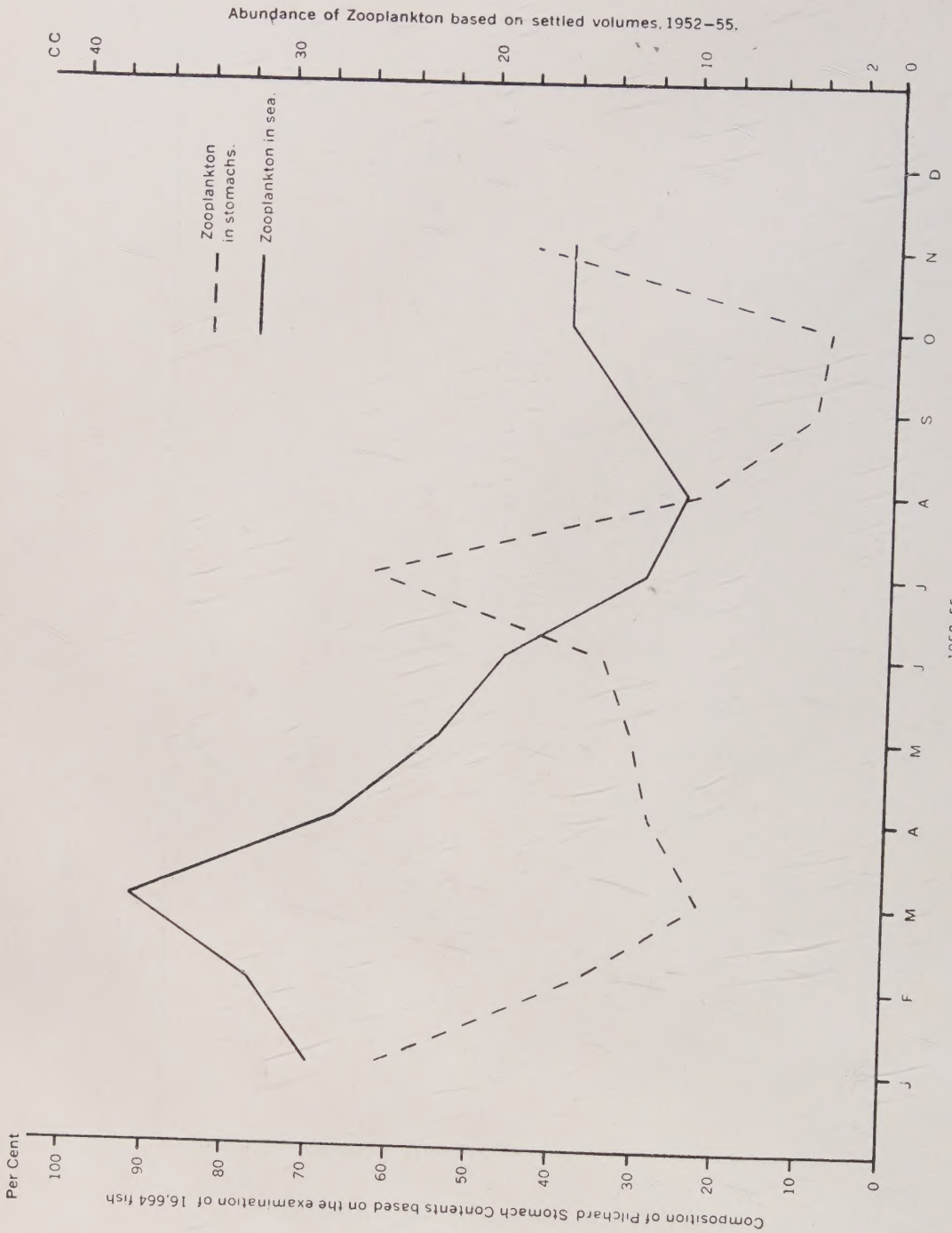


PLATE 17. THE RELATIONSHIP BETWEEN THE ZOOPLANKTON IN PILCHARD STOMACH CONTENTS AND IN THE SEA